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Title:
Effects of Subsonic Aircraft on Aerosols and Cloudiness in the Upper Troposphere and Lower Stratosphere

Summary of Effort, 8/31/94 → 6/30/95

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Introduction:

The primary goal of this project is to analyze the aerosol and meteorological observations obtained during the NASA-sponsored Global Atmospheric Sampling Program (GASP), 1975-1979, for the purpose of compiling a climatology of upper tropospheric/lower stratospheric aerosol properties along en route air corridors during the volcanically-quiescent late-1970's. A second objective is to prepare a climatology of conditions favorable for persisting aircraft contrails, based on GASP temperature, pressure, and humidity measurements.

During GASP, five commercial airliners were instrumented with automated instrument packages which recorded observations of meteorological and particulate properties on-board at 5-minute intervals while the aircraft was above 6 km MSL. These aircraft frequently circum-navigated the Northern Hemisphere. Some observations were obtained in the Southern Hemisphere. The recorded data were processed, combined with interpolated values for local troposphere height, based on the National Meteorological Center operational analyses, and distributed to analysts by the NASA-Lewis Research Center. Due to a lack of funding, a comprehensive study of the aerosol measurements obtained during GASP was never undertaken.

Progress to Date:

The original plan was to obtain the complete GASP archive from the National Climatic Data Center (NCDC). However, it turned out that the archive at the NCDC is incomplete. Much of the GASP dataset was processed just as the program was being phased out. The last third of the processed data tapes were never summarized in formal reports, as had been the earlier ones, and were not included in the archive sent to NCDC. Prof. Greg Nastrom (St. Cloud State University, St. Cloud, Minnesota) graciously agreed to supply copies of the complete archive, which he had obtained directly from NASA-Lewis as part of earlier research activities. We began our work with a small subset of the data, supplied by him as an example. More recently, we obtained a copy of the complete GASP data set now maintained at the National Center for Atmospheric Research, which they, in turn, had recently obtained from Prof. Nastrom.

A collection of relevant NASA "gray literature" reports has been compiled describing the performance and calibrations of the meteorological and aerosol instruments employed in the GASP instrument package. We are beginning to compare readings obtained by different aircraft at nearly the same time in the same meteorological context, as there are likely to be differences in performance between the five separate instrument packages. This comparison will facilitate combining the data from the five instrumentation packages into one database. Although aerosol instrumentation of that day had its limitations compared to today's state-of-the-art, we are working on comparisons to other late-1970's era measurements using instrumentation that has continued in use to this day (i.e. the condensation nucleus and optical aerosol counter measurements made by Profs. Hofmann and Rosen over the past three decades, from Laramie, Wyoming) and will, in this manner, relate GASP measurements obtained in the 1970's to measurements obtained using other instruments, and satellite remote retrievals, during the 1990's.

Meteorological data have been located suitable for use in this study. We are still seeking a low-cost source of satellite observations from the GASP era to aid in classifying the meteorological context of individual GASP observations.

Software has been written to read the archived data and extract the observations relevant to this study. Observations from one several-month period have been extracted and plotted. Corroborating meteorological data are also being plotted. An example of observations from one flight are attached. Figure 1 shows the flight track, originating in Chicago and terminating in San Francisco. Figures 2 and 3 show profiles of aircraft altitude versus local tropopause height, with altitude in Fig. 2 being expressed as pressure altitude in meters, while in Fig. 3 altitude is expressed as pressure in millibars. During much of the flight the aircraft was in the stratosphere. Figure 4 shows that the aircraft was crossing a trough in the upper-air wind pattern, with southwest winds on the eastern side of the trough and northwest winds on the western side. Winds were quite light in the lower stratosphere in the middle of the trough. Figure 5 confirms the interpretation of Fig. 4, showing a broad trough over the central U.S. in the mid-troposphere. The ozone observations in Fig. 6 show the expected high mixing ratios of ozone in the stratosphere, with low values on climbout and descent in the upper troposphere, at the beginning and end of the flight. Figure 7 shows temperatures decreasing near the beginning of the record, as the aircraft climbs, increasing slightly as the aircraft climbs above the tropopause through the middle of the flight, then decreasing near the end of the flight as it descends back below the tropopause, then increasing dramatically as the aircraft descends from the upper troposphere toward the surface. The response of the frost point sensor appears to lag that of the temperature sensor. Figure 8 shows observations from three channels of the optical particle counter. The counts are cumulative with size, with PD2 indicating all particles large enough to be detected by the instrument (larger than 0.9 μm diameter), PD4 indicating particles larger than 1.4 μm, and PD5 indicating particles larger than 3 μm. The cumulative total, PD2, decreases with height above the tropopause (middle portion of flight) while the concentration of PD4- and PD5-size particles increases with distance above the tropopause. The condensation nucleus counter on the instrument package was not working on this flight, but normally indicates concentration of all particles larger than a few hundredths of a micrometer in diameter.

Natural aerosol characteristics in the upper troposphere are determined by upward transport from source regions near the surface, downward transport from source regions in the stratosphere, and in situ nucleation and growth/removal processes. In order to provide background information on which of these processes might be important at the location of a particular observation, various meteorological classification schemes are being tested on the sample data set. Meteorological classifications will be applied to each GASP observation location during selected flights. Criteria being evaluated, in addition to distance above or below the tropopause, include an index of position relative to the usual trough-ridge pattern in the upper troposphere, an index of the amplitude of this trough-ridge pattern, and an index of whether this pattern is (locally) amplifying or diminishing. Also being tested is a measure of distance north or south of the jet stream wind maximum and an index of upper-level cloudiness to be derived from the GASP data themselves as well as satellite data. Our goal is to be able to include enough information to understand the origin of the air being sampled at a given point, along with a qualitative index of its meteorological "age".

We are currently evaluating several database packages and will soon choose one to use to organize our data, including the GASP observations and the meteorological context of each observation. Using the database, we will iteratively evaluate the usefulness of various meteorological criteria in discriminating between samples with different aerosol properties.

Experience to date has shown us that it will be possible to analyze corroborating standard synoptic meteorological data (upper air synoptic wind patterns, satellite cloud patterns, etc.) for only a subset of the 4-year GASP data archive, as this analysis involves time-consuming subjective analyses by people. We anticipate developing some analyses involving both GASP and corroborating meteorological observations for a set of flights that represent as much of the globe, as much of the annual meteorological cycle, and as much of the 4-year period, as possible, and other analyses based on inferences obtained from a much larger set of the GASP data, but without the corroborating meteorological data.

Personnel:

The initial software development has been undertaken by L. Ronald Johnson. Because sufficient funds to support a student research assistant were not sent until the middle of our academic year, and because no students were available to begin a new project at that time, a student was not engaged for this project until this summer. Wen-Yu Chang, the student who has begun working with us, is a computer science graduate student who is experienced in design and use of database software as well as a holder of an advanced degree in Meteorology. Since he has begun to work with us, we have been able to greatly increase our development and analysis efforts.

Travel:

No travel has been undertaken during this course of this research, so far.

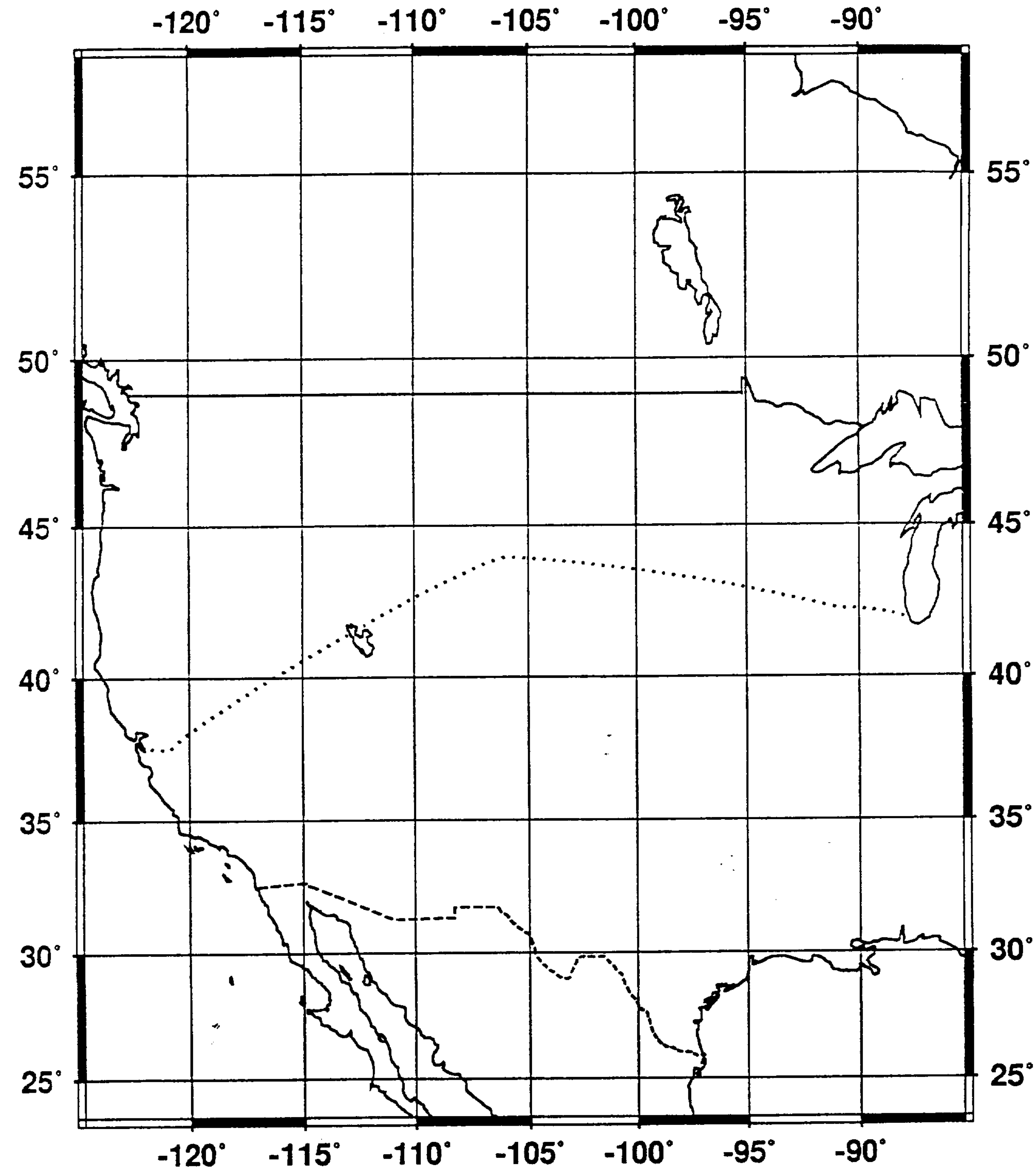
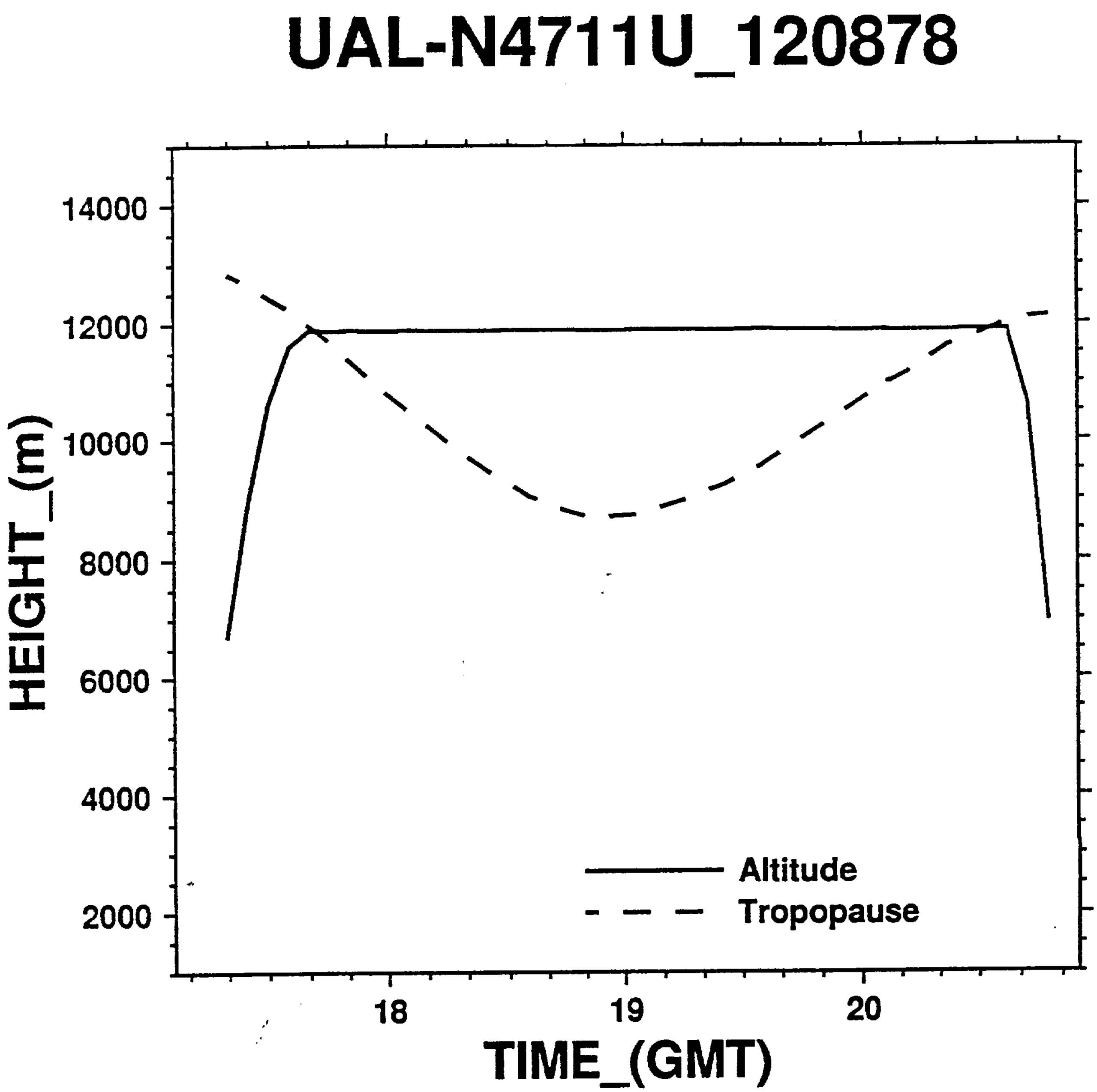


Figure 1


UAL-N4711U_120878
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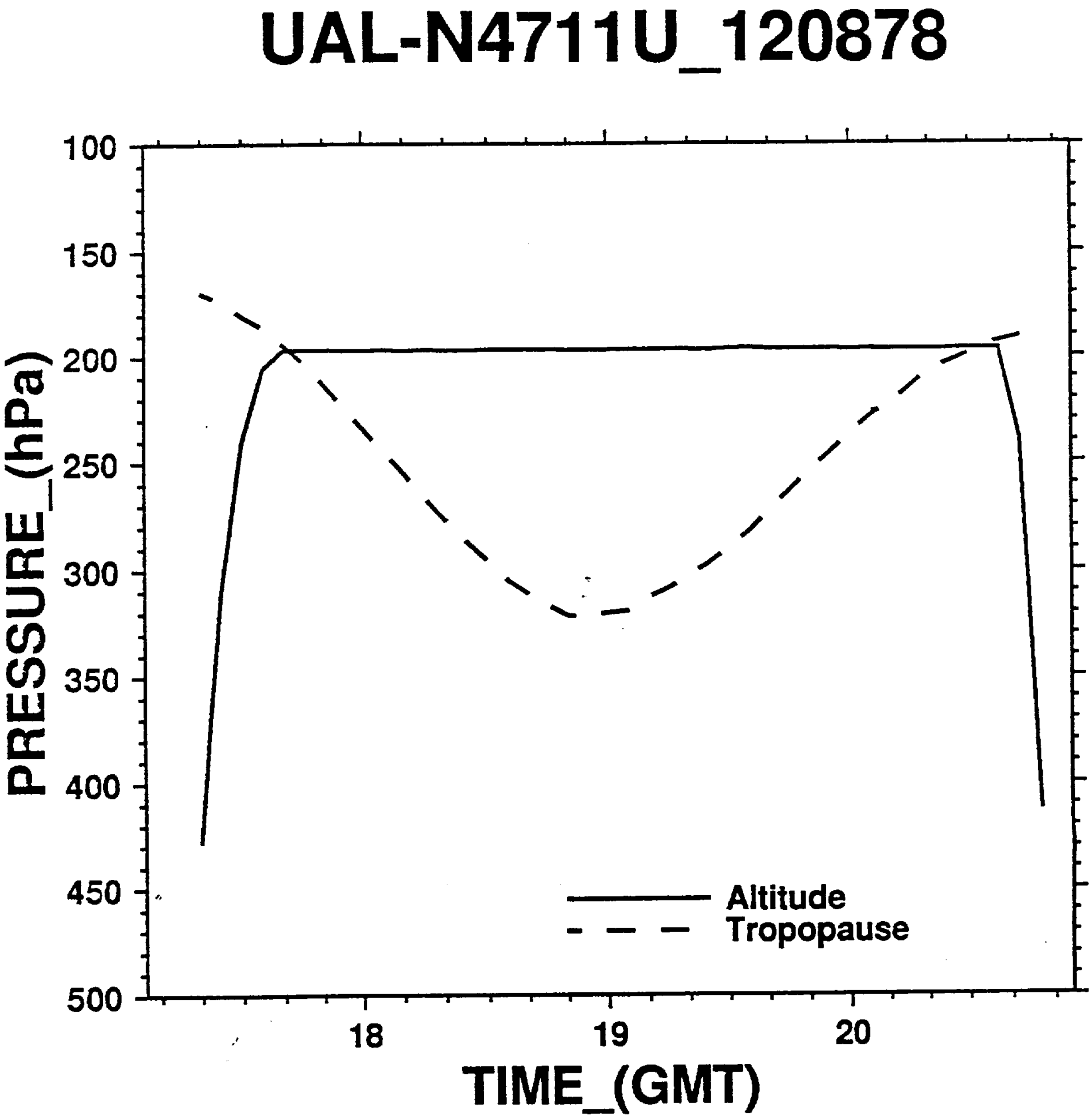
12000
10000
8000
6000
4000
2000
HEIGHT_(m)
18
19
20
TIME_(GMT)
Altitude
Tropopause

Figure 2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PRESSURE_(hPa)
100
150
200
250
300
350
400
450
500
18
19
20
TIME_(GMT)
Altitude
Tropopause

Figure 3

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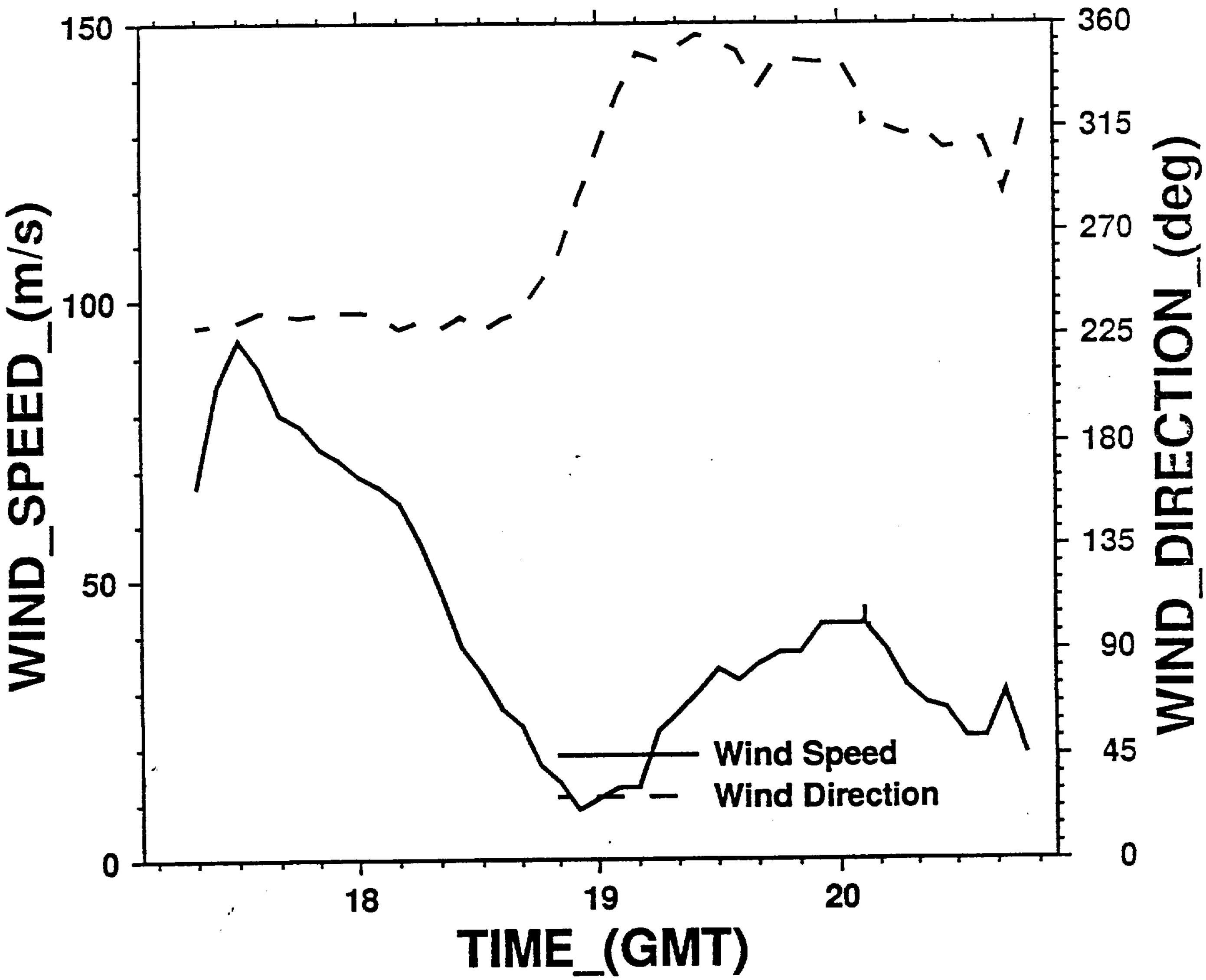


Figure 4

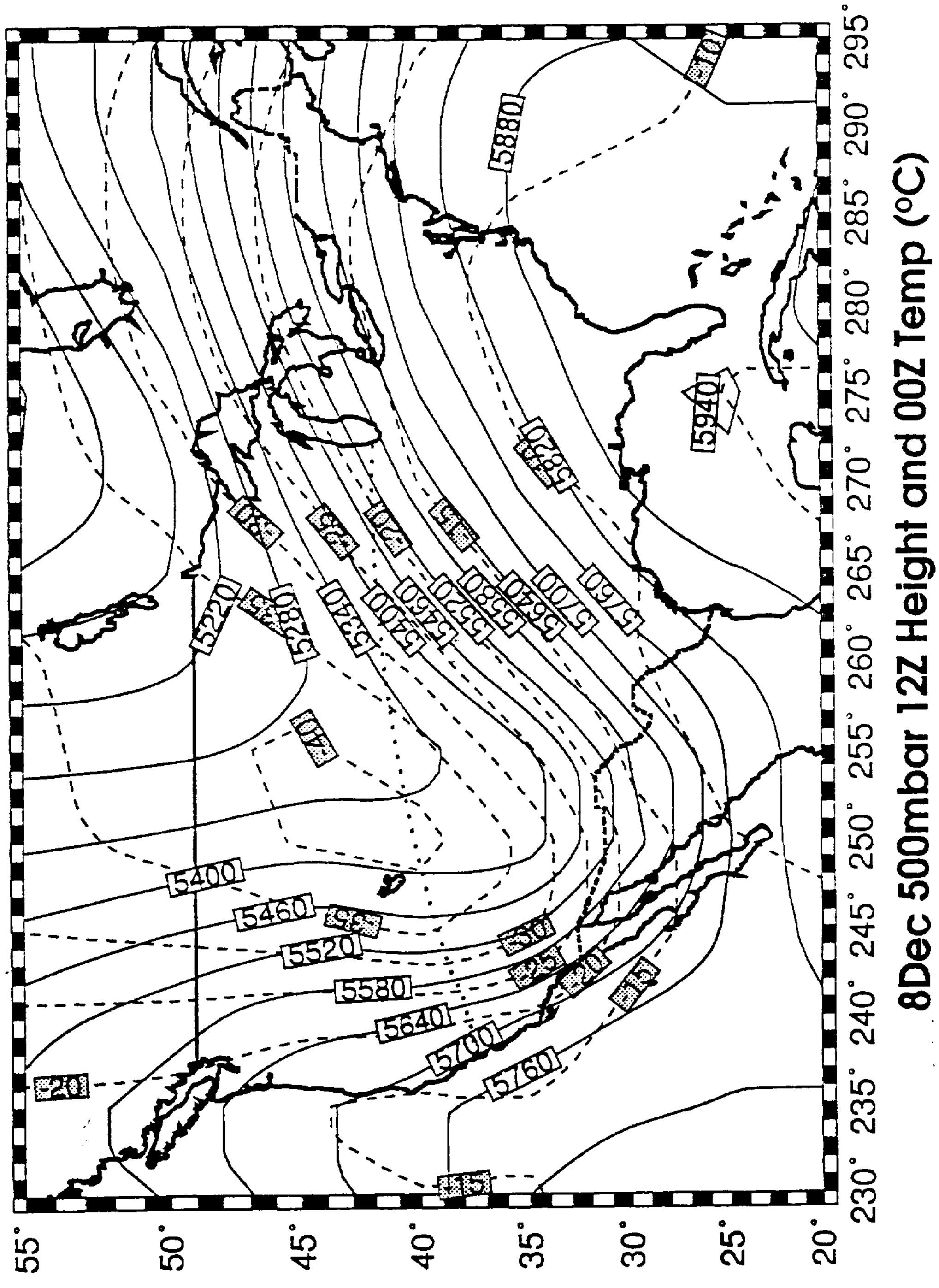
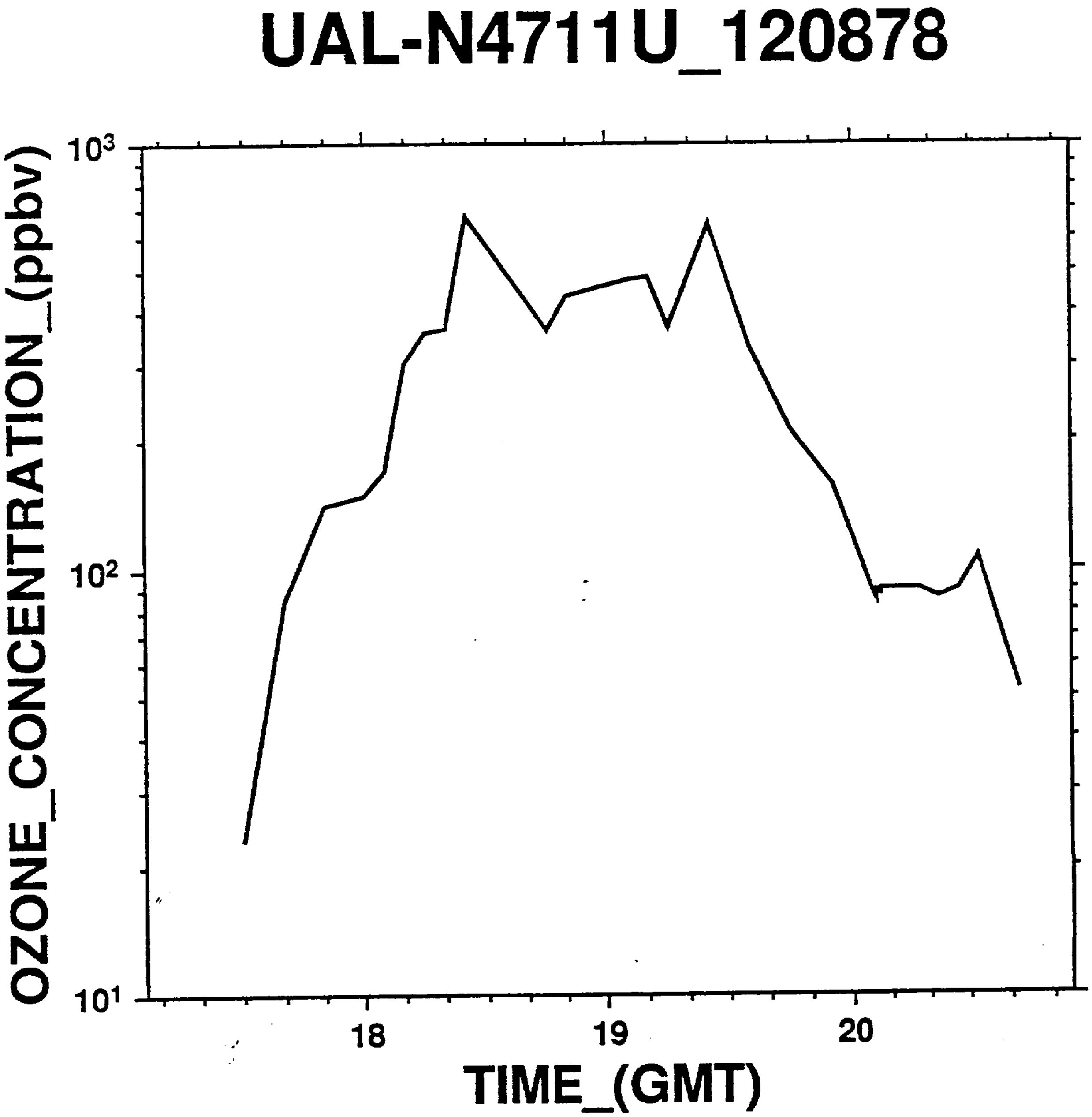


Figure 5


UAL-N4711U_120878
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10²
10¹
18
19
20
TIME_(GMT)

Figure 6

UAL-N4711U_120878

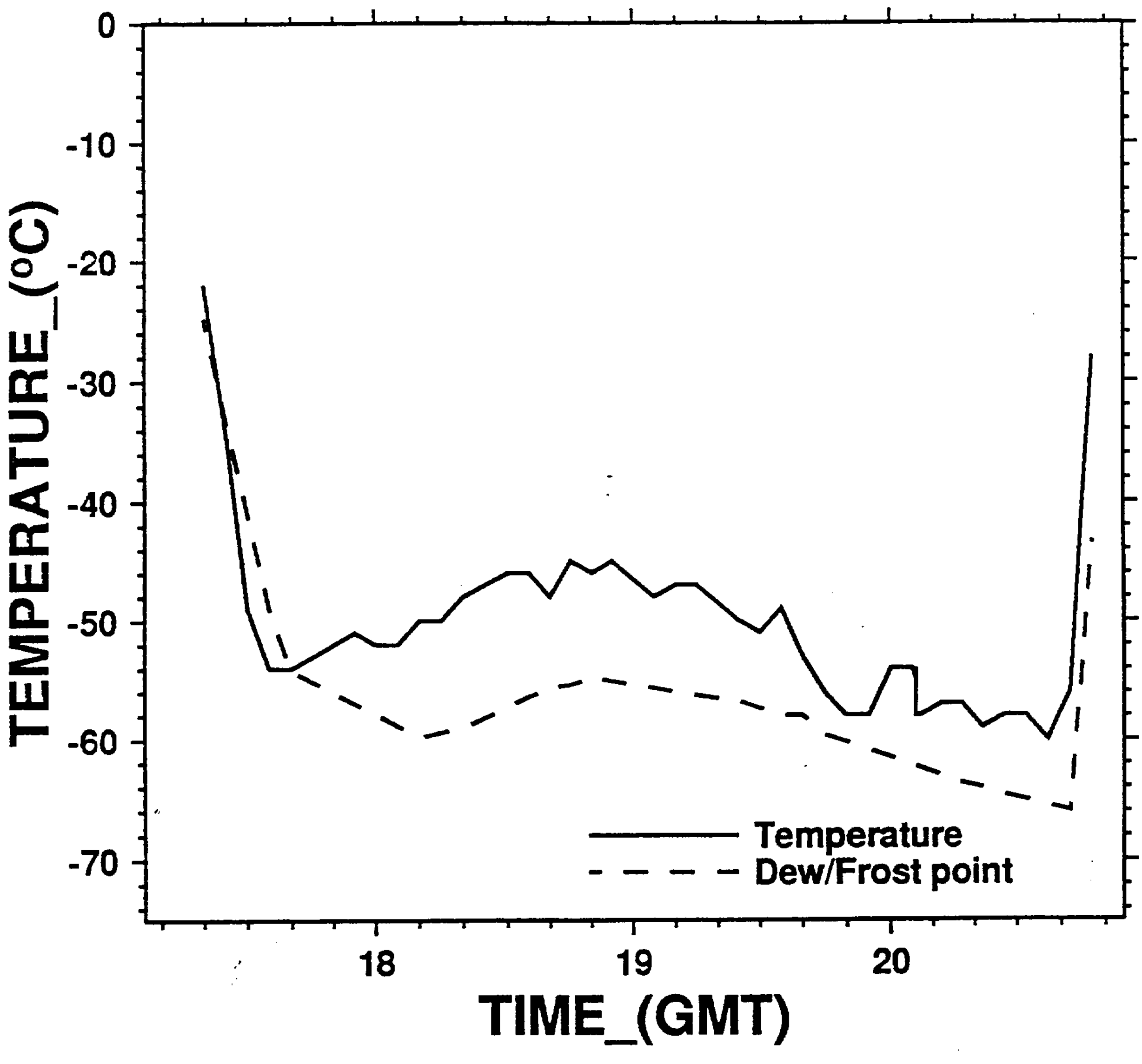

Figure 7

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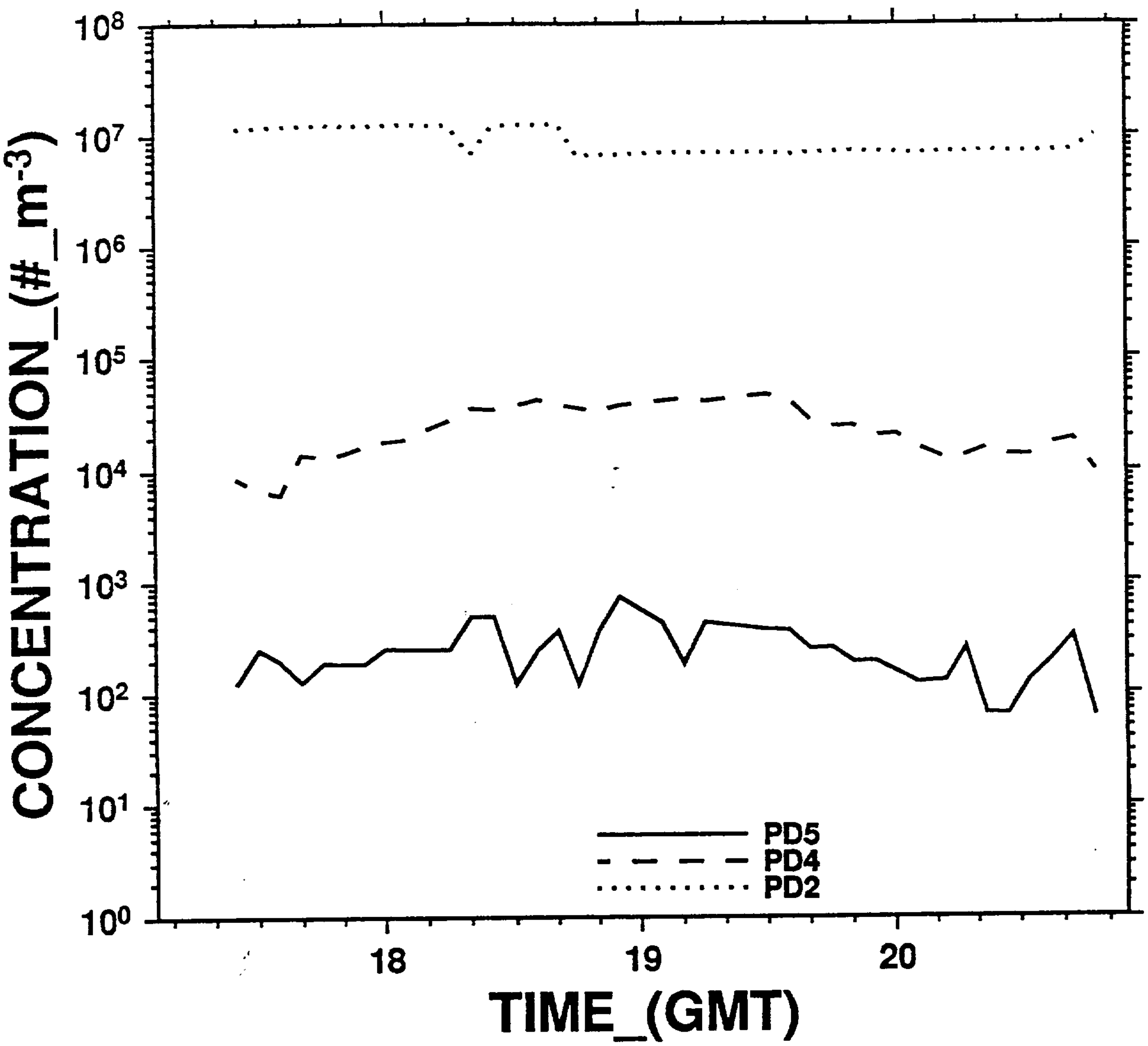

Figure 8